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Abstract: BACKGROUND: The aim of this paper is to show for the first time mortality differentials by level of education for Swiss men and women. This work is of interest to public health efforts in Switzerland as well as for co-operative international research into the determinants of socioeconomic differentials in health and mortality. METHODS: This study is based on a longitudinal data set from the Swiss National Cohort, currently incorporating a probabilistic record linkage of the 1990 Swiss census, and all subsequent deaths until the end of 1997. The study population covers all Swiss nationals aged >/=25 years living in German speaking Switzerland, with 19.7 million person-years and 296 929 deaths observed. Educational gradients were analysed using standardized mortality ratios, multiple logistic regression, and the Relative Index of Inequality (RII). RESULTS: There were sizeable gradients in mortality by education for all age groups and both sexes. The mortality odds ratio decreased by 7.2% (95% CI: 7.0-7.5%) per additional year of education for men, and by 6.0% (95% CI: 5.6-6.3%) for women. In men, we found a steady decrease of the gradient from 13.1% (95% CI: 11.9-14.4%) in the age group 25-39 to 4.5% (95% CI: 4.0-5.0%) in the age group >/=75 years. For women in the age groups under 65 the gradients were smaller; over the age of 40 there was no decrease with increasing age. These results were fairly insensitive to variations in the parameters of record linkage. CONCLUSIONS: Despite a comparatively low overall mortality, Swiss men in the 1990s show larger relative gradients in mortality by education than men in other European countries in the 1980s, with the possible exception of younger men in Italy. In Switzerland there is a sizeable potential for further increasing overall life expectancy by reducing the mortality of those with a lower educational level. The results presented contribute to a reliable assessment of socioeconomic mortality differentials in Europe.

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SPECIAL THEME: SOCIO-ECONOMIC POSITION

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Methods This study is based on a longitudinal data set from the Swiss National Cohort, currently incorporating a probabilistic record linkage of the 1990 Swiss census, and all subsequent deaths until the end of 1997. The study population covers all Swiss nationals aged ⩾25 years living in German speaking Switzerland, with 19.7 million person-years and 296 929 deaths observed. Educational gradients were analysed using standardized mortality ratios, multiple logistic regression, and the Relative Index of Inequality (RII).

Results There were sizeable gradients in mortality by education for all age groups and both sexes. The mortality odds ratio decreased by 7.2% (95% CI: 7.0–7.5%) per additional year of education for men, and by 6.0% (95% CI: 5.6–6.3%) for women. In men, we found a steady decrease of the gradient from 13.1% (95% CI: 11.9–14.4%) in the age group 25–39 to 4.5% (95% CI: 4.0–5.0%) in the age group ⩾75 years. For women in the age groups under 65 the gradients were smaller; over the age of 40 there was no decrease with increasing age. These results were fairly insensitive to variations in the parameters of record linkage.

Conclusions Despite a comparatively low overall mortality, Swiss men in the 1990s show larger relative gradients in mortality by education than men in other European countries in the 1980s, with the possible exception of younger men in Italy. In Switzerland there is a sizeable potential for further increasing overall life expectancy by reducing the mortality of those with a lower educational level. The results presented contribute to a reliable assessment of socioeconomic mortality differentials in Europe.

Keywords Census, cohort studies, data linkage, death records, differential mortality, educational status, Europe, female, inequality, longitudinal, mortality, record linkage, socioeconomic factors, Switzerland

In the last decades of the 20th century, a resurgence of interest in health inequalities by socioeconomic status (SES) could be observed. During this time, several comprehensive reviews were published covering various European countries.[1–11] An overview of the recent European situation can be gained from the publications of the Mackenbach group.[12–16] The reason for the renewed interest is the accepted view that in most countries an accentuation of inequalities has occurred over the last 20 years.[17–22] In addition, some recent studies found evidence

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of causes for socioeconomic health disadvantages in early life as well as for factors perpetuating such health disadvantages over generations.[23,24] This lead to policy initiatives explicitly aimed at reducing SES-related health inequalities.[25,26]

A promising line of research is to compare the socioeconomic health differentials of many countries. The databases used by Kunst *et al.*[12,13] were of varying quality: data from representative longitudinal studies were available for France, England and Wales, and the Nordic countries, while some data incorporated into their analyses were either cross-sectional or non-representative (Switzerland, Italy, Spain, Portugal). There is consensus about the limitations of cross-sectional data (e.g. descriptive instead of analytical approach, numerator/denominator bias, ecological fallacy). Thus there is an interest in obtaining solid longitudinal evidence from other European countries.

Research into mortality according to education

Educational and income information being rarely available on death certificates, research into socioeconomic mortality differentials in Europe is based mainly on occupational information. Consequently, such research is centred on males of working age. Analysis of mortality by education is less prone to such imbalance. Most studies of mortality by education have been conducted in the Nordic countries[4,12,22,27–31] and the US.[32–37] Additional knowledge is contributed by longitudinal studies from England, France and Italy,[12,13] Austria,[38] and Israel,[39] as well as by some cross-sectional studies.[16,40,41] All except one study[36] reported substantial mortality gradients by educational level, with two additional exceptions concerning older females[37] or older males.[39] However, most studies are restricted to people under 70, with only a few studies presenting detailed age-specific results for those aged over 65 years.[22,27,38]

The reported inequalities in mortality by education are generally significantly larger for males than for females. However, not all studies have found a difference in educational mortality gradients by gender,[27,31,36] and some have found a stronger gradient for females,[30,39] or shown inconsistencies according to the time period[4] or the life stage.[38] Various explanations for the smaller gradient in women were provided: a different pattern of risk factors[16] and hence differences in the distribution of causes of death,[16,29] as well as in employment and family status.[28] As a rule, risk ratios decrease with increasing age, though this pattern is inconsistent in females.[38,39]

Research into health inequalities in Switzerland

Switzerland has a long history of sporadically presenting mortality data by occupational categories.[42] Between 1910 and the 1980s there were few publications on this topic. In the 1980s, renewed interest resulted in studies of cancer mortality by occupation[43,44] and mortality by social class.[42,45,46] These efforts culminated in the participation in the above mentioned EU consortium project.[12,14,15] However, all these analyses were cross-sectional in nature and, lacking other socioeconomic information in death records, restricted to occupationally based categories.

Representative data on reported morbidity, symptoms, and risk factors in relation to education and other socioeconomic variables have been available from health surveys since the early 1980s,[47–51] the latest being the Swiss Health Survey of 1997 for which our team has prepared a report on SES by education, occupational group, and income.[52]

However, so far there has been no data set available for studying morbidity or mortality with a longitudinal design. This has changed with the inception of the Swiss National Cohort Study, of which this paper is the first report. The study population selected for the present analysis is representative of the German speaking part of Switzerland and covers more than 7 years of follow-up. This study is important for Switzerland as it is the first analysis of Swiss mortality data by educational class, and the first such analysis including women.

Aims of this study

The primary aim of the present study was to quantify mortality differentials by education in Switzerland. This is of interest for Swiss public health and health policy and may serve to support political interventions to reduce health differentials. However, the study has a claim to wider interest. In previous European co-operative studies, it became evident that there is little solid knowledge about socioeconomic differentials in mortality for the central, eastern, and southern European regions.[16] Even for Italy, Spain, and Portugal, it remains unclear whether the findings published so far can be considered representative for these countries. Thus, the Swiss National Cohort Project provides solid evidence of the magnitude and consistency of health differentials by education for a region of Europe with limited corresponding information. The study also adds to the knowledge about socioeconomic differentials in the 1990s.

Material and Methods

Setting and educational system

Politically, Switzerland is a federation of 26 cantons, each having a high degree of internal autonomy. For example health and education are in the cantonal domain, and there are major variations between the cantons in these systems.[49,53] The country comprises three major cultural groups: the German Swiss (17 cantons entirely German speaking, 2 predominantly; 72% of total population), the French Swiss (4 cantons entirely French speaking, 2 predominantly; 23% of total population) and Italian Swiss (1 canton; 4% of total population) (Figure 1).

School entry age varies between the cantons, but in German-speaking Switzerland is between the age of 6 and 7. Nine years of schooling are compulsory, resulting in a minimum school leaving age of 15 years. Before retirement age, the category 'education not mentioned' mainly concerns people living in institutions. After compulsory schooling a majority of men and women have additional education, mainly 2–4 years of vocational training, or (less frequently) 3–5 years of high school including teachers' training colleges, which accounts for the female preponderance in this category. Older women have mostly only completed compulsory school. Generally, upper vocational education and technical colleges follow vocational training, whereas university schooling requires a high school education. A university degree is usually obtained by the age of 25.

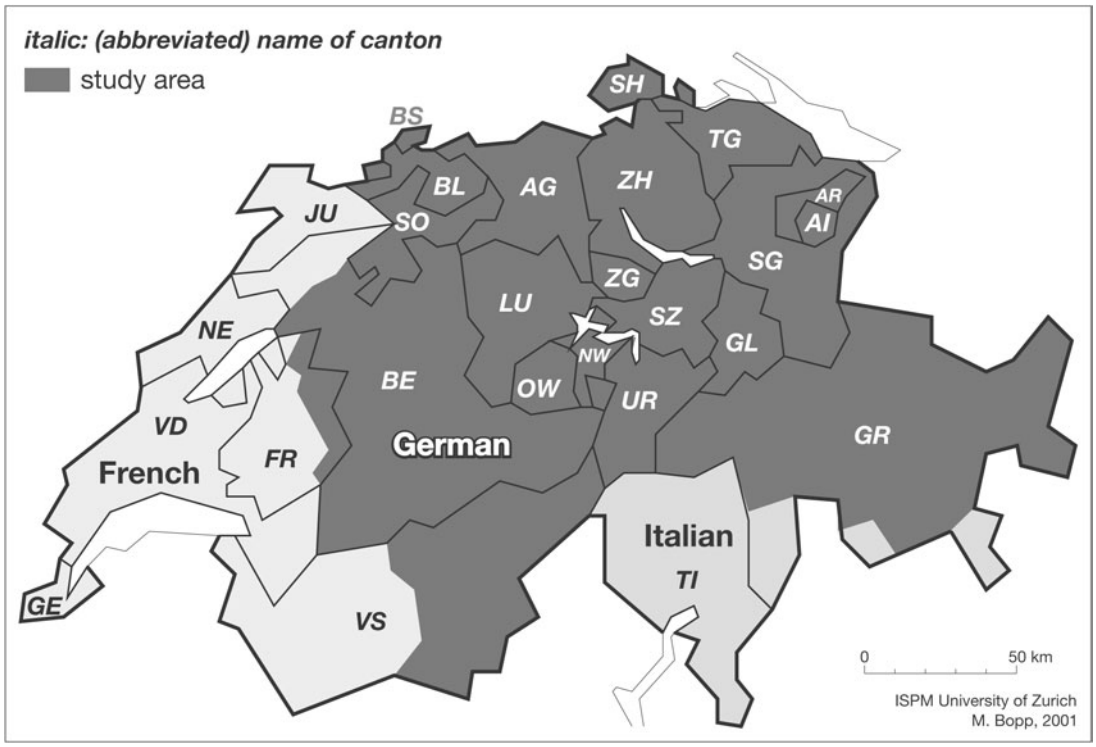


Figure 1 Linguistic areas of Switzerland

AG: Aargau, AI: Appenzell Inner-Rhoden, AR: Appenzell Ausser-Rhoden, BE: Bern, BL: Baselland, BS: Basel-Stadt, FR: Fribourg, GE: Geneva, GL: Glarus, GR: Graubünden, JU: Jura, LU: Lucerne, NE: Neuchâtel, NW: Nidwalden, OW: Obwalden, SG: St Gallen, SH: Schaffhausen, SO: Solothurn, SZ: Schwyz, TG: Thurgau, TI: Ticino, UR: Uri, VD: Vaud, VS: Valais, ZG: Zug, ZH: Zürich.

Study population

We obtained all anonymous records of the Swiss census of 4 December 1990 from the Swiss Federal Office of Statistics. This database was used as a population register. Mortality analyses for foreign nationals living in Switzerland are seriously biased by numerator/denominator problems and migration effects.[54,55] For this reason and in view of internationally different educational systems we excluded the death and census records of foreign nationals. Substantial differences in the systems of education between the Swiss cultural groups (53, ref. 56, p. 686) and in the proportions of successfully linked records (see section on record linkage) led us to restrict the present analysis to Swiss nationals living in predominantly German-speaking areas. As outlined above, university schooling is generally not completed before the age of 25. We therefore applied a lower age limit of 25 years. Of a total of 4.197 million Swiss nationals living in the German-speaking parts of the country, 1.276 million were younger than 25 years. Thus, the study encompassed 2.921 million people and 19.735 million person-years.

Deaths

We obtained all anonymous death records for the years 1990–1997 from the Swiss Federal Office of Statistics. Between 5 December 1990 (the day after the census) and 31 December 1997, 443 219 deaths were registered in Switzerland. Of these, we excluded 3628 deaths of children born after the 1990 census, 28 397 deaths of foreign nationals, and 6777 deaths of Swiss nationals aged <25 years at the date of the census. Of the remaining 404 417 deaths, 73.4% concerned individuals who had lived in the study area; of these 145 206 were male and 151 723 were female.

Record linkage

Death certificate records and census records were linked on the basis of coinciding key variables (sex, birth date, commune of residence, marital status, and religious denomination). A probabilistic record linkage method was used[57,58] and several scenarios with different weighting of the key variables were executed in order to obtain optimal linkage quality. Linkage was done in two phases. In phase A, each death record was classified according to the number of potential counterparts in the census (Table 1) and then processed. Using strict criteria for linkage (no discordance in any key variable, no further record with the same combination of key variables) 73.3% of death records could be linked. Under these criteria, even a single minor discordance prevented linkage. In phase B, all death records not strictly linked in phase A were successively processed through passes 1 to 4. For 16.2% of death records this meant a search for a better link, while 10.5% still had no link in phase A. Inspection showed that strict linkage excluded some good links. In the default version we therefore focused on a threshold permitting linkage with one major or several minor discordances depending on pocket size (e.g. deviations leading to a record linkage in a small village might not be acceptable in a larger

Table 1 Swiss National Cohort: Record linkage procedure (only Swiss nationals aged over 25 and living in German-speaking parts of the country)

	Key variables[a]	% of death records linked under criteria: Strict	Default	Liberal	% without acceptable link	Total % of death records	Remarks (CR = corresponding census record)
Phase A							
Category							
Completely unique	R,D,N,S	61.9%	65.5%	66.2%	0.2%[b]	66.4%	Only one CR
Partially unique	R,D,N,S | MS,RD	11.4%	11.6%	11.6%	0.2%[b]	11.8%	Only one CR
Not unique	R,D,N,S,MS,RD	–	1.9%	5.6%	5.7%[b]	11.3%	Several CR
No corresponding census record		–	–	–	10.5%	10.5%	No CR in same commune
Total						100.0%	N = 296 929
Linked		73.3%	79.0%	83.4%			
Not linked		26.7%	21.0%[b]	16.6%[b]	16.6%[b]		
Phase B							
Pass 1	R,N,S	–	3.9%	5.0%	11.7%		
Pass 2	D,N,S	–	5.7%	7.6%	4.1%		
Pass 3	R,D,S	–	0.1%	0.1%	4.0%		
Pass 4	R,D,N	–	–	0.2%	3.8%		
Total new links, phase B		–	9.6%	12.9%			
Total links, phases A+B		73.3%	88.6%	96.2%			N = 263 122 = 88.6%

[a] R: place of residence (commune), D: birthdate (YYYYMMDD), N: nationality, S: sex, MS: marital status, RD: religious denomination.

[b] Including acceptable links that were abandoned in phase B in favour of a more plausible link.

municipality). In this way, 88.6% of death records could be linked. Excluding only the improbable linkages ('liberal criteria'), 96.2% of the death records could be linked. Information on record linkage procedures and the quality of linkage are given in detail elsewhere.[54] An investigation of the 11.4% of deaths not linked for the default version revealed that this proportion was higher for inhabitants of larger cities (27%), for younger people (24% in the ages 25–34), those who were divorced (15%), and for women (13%).

We also did sensitivity analyses excluding cities with more than 50 000 inhabitants, the locations where linkage quality was lowest. Even excluding these larger cities, our study comprised 60% of all Swiss nationals aged ⩾25 years. Within this group in the default version 94.3% of death records could be linked to a census record.

Measures of mortality

Age was determined at the time of the census, i.e. 4 December 1990. Mortality rates were calculated for 5-year age-sex classes using numbers of deaths and person-years at risk. Individuals registered in the census that could not be linked to a death record were assumed to be alive at the end of the follow-up. Based on the resulting age-specific rates, standardized mortality ratios for all educational categories were determined by the indirect method (basis: study population). Inequalities were quantified by comparing standardized mortality ratios between the different educational categories as well as by measures of slope such as the Relative Index of Inequality (RII).[59,60] The RII adjusts for the variation in the size of the individual educational groups and therefore can be considered to be an appropriate inequality index for comparing countries with respect to the size of health inequalities by educational level.[12] The association of mortality with the number of years of education was analysed using individual data and logistic regression with years of education and age as independent variables (age in years, linear and quadratic; the quadratic term was introduced to allow for a progressive increase of mortality with age).

Results

Table 2 presents the prevalence of the nine categories of education used in the 1990 census for the study population. The numbers of years of education in the first column were obtained from the Swiss Statistical Yearbook; (ref. 61, p. 332) they are fairly high in Switzerland compared with other European countries (Cavelaars,[10] Kunst *et al.*[12]). The proportions of each educational category are given separately for men and women before and after age 65, the common retirement age for men. A shift to higher education may be observed in the younger age groups. This shift is more marked for women than for men. Given the small numbers in some educational categories, it seemed justified to aggregate the nine educational categories into four groups as indicated in Table 2.

Table 3a presents male relative mortality by age (on 4 December 1990) and educational group. Generally, the rank order of the relative risks is the same for the younger as for the older age groups, with lower mortality for those categories with longer duration of education. However, the risk elevation for those with no secondary education is much more pronounced in the younger age groups. Table 3b presents the analogous information for Swiss women. The smaller gradients for women are noteworthy as is the small mortality difference between female university graduates and other female tertiary graduates (except at ages ⩾75 years).

Figure 2 shows the mortality rates by age group and educational group. There are large relative differences in mortality between educational groups for younger ages and smaller differences for the older ages, especially for men. However, in men the relative position of each educational group remains the same for all ages under 90, and the absolute differentials do not decrease with age. A higher level of education goes along with reduced mortality, with risk ratios exceeding 3 in younger men. For women in the younger and middle age groups the gradients were flatter; over age 45 there was no decrease with increasing age. Except for some inconsistencies in the small group of female

Table 2 Highest educational level in 1990 (proportion of population), Swiss nationals living in German speaking areas

		Ages 25–64		Ages 65+	
	Years of education[a]	Males (N = 1 080 175)	Females (N = 1 157 018)	Males (N = 273 516)	Females (N = 413 244)
Graduate school (university)	19	8.0%	2.7%	5.7%	0.8%
Tertiary education		20.2%	11.1%	10.8%	4.4%
Technical college	16	5.3%	1.2%	2.3%	0.5%
Upper vocational education	14	11.7%	3.8%	6.9%	1.4%
High school	13	3.2%	6.2%	1.6%	2.6%
Vocational education	12	57.6%	55.2%	46.6%	30.1%
No secondary education mentioned		14.2%	31.0%	36.8%	64.7%
Other education	9	0.5%	1.0%	0.6%	0.9%
Compulsory school	9	12.3%	28.1%	31.6%	57.7%
Incomplete compulsory schooling	8	0.4%	0.5%	0.6%	0.9%
Education not mentioned	8	1.0%	1.4%	4.0%	5.4%

[a] Source: Statistical Yearbook of Switzerland (ref. 61, p. 332).

Data source: Swiss Federal Office of Statistics, 1990 census.

Table 3 Standardized mortality ratios 1990–1997 (95% CI) by educational level, Swiss National Cohort: Swiss nationals aged ⩾25 years and living in German speaking areas (educational categories cf. Table 2).

	Age at start of follow-up (years)				
	25–39	40–54	55–64	65–74	75+
a) Men					
Linked death records	**4617**	**11 382**	**18 996**	**36 409**	**59 365**
Highest educational level					
Graduate school (university)	61 (54–70)	59 (54–64)	63 (58–67)	71 (68–75)	79 (76–82)
Tertiary education	71 (66–77)	70 (67–73)	77 (74–81)	79 (76–81)	89 (86–91)
Vocational education	99 (95–103)	102 (99–104)	96 (94–98)	95 (94–96)	98 (96–99)
No secondary education mentioned	196 (184–209)	159 (153–165)	135 (131–138)	120 (118–122)	108 (107–110)
b) Women					
Linked death records	**2305**	**6802**	**10 852**	**25 060**	**87 334**
Highest educational level					
Graduate school (university)	78 (60–99)	82 (68–97)	70 (56–86)	83 (72–96)	75 (68–83)
Tertiary education	79 (70–89)	80 (73–87)	78 (72–85)	77 (73–82)	85 (82–88)
Vocational education	93 (88–98)	94 (91–97)	92 (89–94)	87 (85–89)	90 (89–91)
No secondary education mentioned	139 (129–150)	116 (112–120)	110 (107–113)	110 (108–111)	105 (104–106)

Data source: Swiss Federal Office of Statistics, statistics of death cases and causes of death; 1990 census.

university graduates, the relative position of the educational groups under age 90 does not depend on the age. The small group of younger men and women not having completed compulsory education were found to have very unfavourable mortality risk ratios (data not shown).

A multiple logistic regression, including all subjects aged ⩾25 years at the 1990 census, with age (linear and quadratic) and estimated years of education as independent variables, showed that for men the mortality odds ratio decreased by 7.2% per year of education (95% CI: 7.0–7.5%), while for females the reduction was 6.0% (95% CI: 5.6–6.3%). The slightly smaller gradient for women applies only for the age groups under 65. In men, there was a steady decrease of the gradient from 13.1% (95% CI: 11.9–14.4%) in the age group 25–39 to 4.5% (95% CI: ⩾4.0–5.0%) in the age group ⩾75 years. For women in the age groups under 65 the gradients were smaller and over the age of 40 there was no decrease with increasing age (Table 4).

Sensitivity analyses

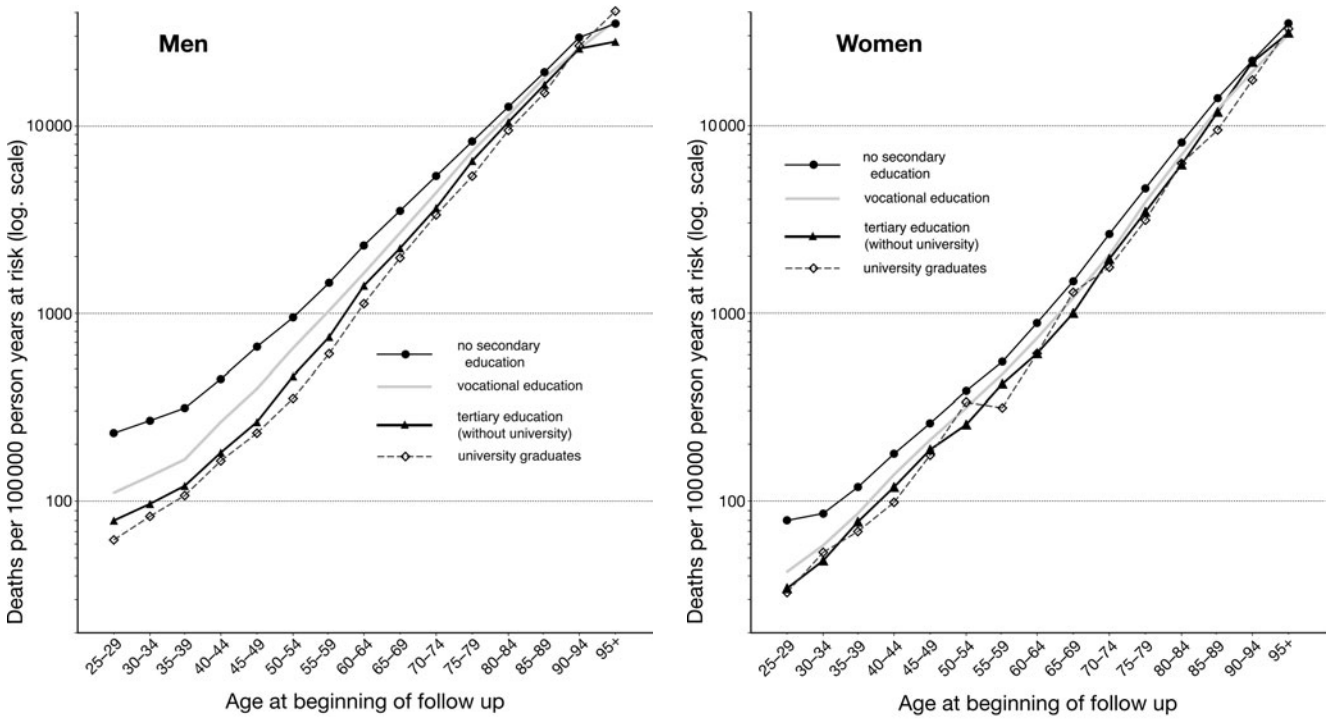
The above analyses were repeated with different levels of stringency for the record linkage (Table 4). For men and women aged <75 years, the slope in the percentage decrease in mortality with one year of additional education increased considerably when applying strict criteria for linkage (definition in Methods). Applying liberal linkage criteria caused only a modest reduction of the slope in most age groups (with the exception of 25–39 years). Exclusion of the seven cities with more than 50 000 inhabitants showed only minor changes (table available from authors).

International comparison

Table 5 compares the RII based on the four educational groups from Table 3 with results from five other European countries (table adapted from Kunst *et al.*[12]). For men aged 45–59 years, the 1990s Swiss gradient in mortality by education is clearly the steepest, for men aged 30–44 years it is exceeded only by Italy. For women, the Swiss gradients are comparable to other countries.

Discussion

For Switzerland, this is the first representative longitudinal study of mortality, the first study of mortality differentials by educational level as well as the first representative study of



Data source: Swiss Federal Office of Statistics, statistics of death cases and causes of death; 1990 census.

Figure 2 Age-specific mortality rates 1990–1997 by educational level, Swiss National Cohort: Swiss nationals living in German speaking areas; age calculated on 4 December 1990

mortality gradients by socioeconomic status for women. As Kunst (ref. 13, p. 218) has stated, 'only a few countries have detailed, reliable and nationally representative data on socio-economic differences in mortality'. In view of this and given the fact that only a few studies have dealt with women and people aged >65 years, this study supplies new evidence for research into socioeconomic inequalities in health and their cross-cultural comparison.

For our German Swiss study population, we found sizeable gradients in mortality by education for all age groups; the pattern of mortality was fairly consistent between ages 25 and 89. The significantly larger gradients for males than for females in those aged under 65 are in accordance with the majority of the literature (Introduction). As in other studies,[22,27,33,38] the relative inequalities for males decreased with increasing age. For females over 45 this is not the case, a finding that is difficult to judge given the sparse and rather inconsistent results from other European studies.[28,38]

What are the reasons for the large mortality gradients by education in Swiss males in the 1990s compared with the data published by Kunst *et al.*?[12] This difference could be the result of comparing Swiss data from the 1990s with data from other European countries from the 1980s. It cannot be ruled out that the steeper Swiss gradients reflect the general widening of socioeconomic differentials reported from several countries. However, given the stable economic situation of Switzerland and today's understanding of origins of social differences in health, such a substantial increase within only a decade seems rather unlikely. As mentioned, the Swiss studies focusing on the early 1980s are not methodologically comparable with our study (unlinked cross-sectional design, based on occupation instead of education). However, the reported risk ratios reached a similar size.

Are the results obtained here reliable? Incomplete census forms were quite rare in the 1990 Swiss census and therefore were not a major source of differential misclassification. A source of bias could be death certificates not linked at all or linked to the wrong census record. With a strict record linkage threshold, the probability of incorrect linkages could be minimized, but only at the price of losing a substantial number of probably correct linkages and a selection bias in favour of the least mobile groups, e.g. homeowners and the sick. Indeed, the more restrictive the linkage requirements, the steeper were the gradients. With liberal linkage criteria, the probability of incorrect linkage increases and the resulting non-differential misclassification will dilute the real differences. As a compromise, we chose a threshold balancing false-positively and false-negatively linked records, permitting the linkage of 89% of death records. There is still some room for bias because there were subgroups for which the fraction of unlinked deaths was larger. Thus, the results for city dwellers and for those aged <40 years may be less reliable. However, our sensitivity analyses indicate that these effects are likely to be small.

Switzerland is a country with high life expectancy. However, life expectancy is determined more and more by the mortality risks of the elderly. Unfavourable mortality in younger ages may be masked by a favourable situation in the older ages. This is the case in Switzerland, with elevated mortality rates for those aged 20–49 years[62] compared with other western European countries. Together with our finding of a particularly steep

Table 4 Relative reduction of mortality per one additional year of education[a,b] in percentage in function of record linkage stringency and age group, Switzerland 1990–1997, Swiss National Cohort: German speaking areas

	Reduction of mortality per year of education in % (95% CI) (*linked deaths*)		
	Linkage stringency[c]		
Age group[d]	Strict	Default	Liberal
Men			
25–39	17.0 (15.6–18.5) *(3158)*	13.1 (11.9–14.4) *(4617)*	10.8 (9.7–11.9) *(5604)*
40–54	13.4 (12.5–14.2) *(8920)*	11.2 (10.5–11.9) *(11 382)*	10.8 (10.1–11.5) *(12 390)*
55–64	10.4 (9.8–11.1) *(15 201)*	8.8 (8.2–9.4) *(18 996)*	8.3 (7.7–8.8) *(20 338)*
65–74	7.5 (7.0–8.0) *(30 146)*	6.7 (6.3–7.2) *(36 409)*	6.4 (6.0–6.8) *(38 846)*
75+	4.1 (3.7–4.6) *(50 900)*	4.5 (4.0–5.0) *(59 365)*	4.3 (3.9–4.8) *(63 386)*
Women			
25–39	13.0 (10.7–15.4) *(1576)*	8.9 (6.9–10.9) *(2305)*	7.0 (5.1–8.8) *(2768)*
40–54	7.4 (6.0–8.7) *(5242)*	5.9 (4.7–7.1) *(6802)*	5.3 (4.1–6.4) *(7452)*
55–64	7.9 (6.7–9.0) *(8640)*	6.0 (5.0–7.0) *(10 852)*	5.1 (4.1–6.0) *(11 746)*
65–74	8.0 (7.2–8.8) *(20 335)*	6.6 (5.9–7.3) *(25 060)*	5.9 (5.2–6.6) *(27 229)*
75+	4.8 (4.3–5.4) *(73 675)*	5.6 (5.1–6.1) *(87 334)*	5.0 (4.5–5.5) *(96 001)*

[a] Estimated years of education, cf. Table 2.

[b] Logistic regression with years of education and age (linear and quadratic) as independent variables.

[c] See 'Record linkage' in Methods.

[d] Age in fulfilled years at 4 December 1990.

Data source: Swiss Federal Office of Statistics, statistics of death cases and causes of death; 1990 census.

Table 5 Magnitude of mortality differences by educational level: the Relative Index of Inequality (RII)

		Age at death	
		30–44 years	45–59 years
Country	**Period (nc[a])**	RII (95% CI)	RII (95% CI)
Men			
Finland	1981–1990 (3)	3.12 (2.93–3.31)	2.41 (2.20–2.53)
Norway	1980–1990 (3)	3.31 (3.02–3.63)	2.09 (1.98–2.21)
Denmark	1981–1990 (3)	2.40 (2.23–2.58)	1.81 (1.72–1.90)
France	1975–1989 (4)	n.a.	2.45 (2.35–2.55)
Switzerland	1990–1997 (4)	3.53 (3.15–3.96)	3.12 (2.90–3.36)
Italy	1981–1982 (4)	3.71 (3.23–4.27)	1.73 (1.57–1.92)
Women			
Finland	1981–1990 (3)	2.54 (2.29–2.82)	1.71 (1.59–1.85)
Norway	1980–1990 (3)	1.89 (1.66–2.16)	1.66 (1.53–1.81)
Denmark	1981–1990 (3)	1.89 (1.73–2.08)	1.70 (1.60–1.80)
France	1975–1989 (4)	n.a.	2.16 (2.03–2.29)
Switzerland	1990–1997 (4)	2.06 (1.76–2.40)	1.60 (1.46–1.75)
Italy	1981–1982 (4)	1.88 (1.54–2.28)	1.26 (1.07–1.47)

[a] Number of educational categories.

Source: Kunst *et al.* (ref. 12, p. 73); Switzerland: calculated from Swiss National Cohort.

educational gradient in mortality in this age group, a focus for prevention efforts is clearly identified. As the differentials in mortality by education also apply to older age groups, there is sizeable potential for further increasing overall life expectancy by reducing the mortality of those with a lower level of education.

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KEY MESSAGES

- Given the relative scarcity and often limited representativity of European longitudinal studies, the Swiss National Cohort Study supplies new evidence of inequalities in health by education.
- In German speaking Switzerland in the 1990s there were substantial gradients in mortality by education for all ages between 25 and 90 and both sexes.
- Overall, the mortality odds ratio decreased by 7.2% (95% CI: 7.0–7.5) per additional year of education for men, and by 6.0% (95% CI: 5.6–6.3) for women.
- In those aged under 65, gradients for males were significantly larger than for females.
- The relative inequality in mortality by education of Swiss men under 60 years is among the largest published so far.

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Commentary: Explanations of the difference in mortality risk between different educational groups

David Blane

Bopp and Minder's paper[1] is the most welcome first report from the Swiss National Cohort Study. This study links data from the 1990 Swiss national census with subsequent death records, so far 1990–1997. The study supplements the cross-sectional Swiss Health Survey, providing the first longitudinal data on the social distribution of health, as indexed by mortality, in Switzerland.

Sizeable gradients in mortality by education are demonstrated at ages 25 years to 75+ years. At ages 40–54 years, for example, the standardized mortality ratio of male graduates is 59, compared with 159 for men who did not record any secondary education. Some abatement of this relationship is found among women, and at older ages. As Bopp and Minder detail meticulously, these findings are consistent with those from most other rich countries. They point to the relevance of these results for health policy and for the design of interventions to reduce social inequalities in health. My comments concern these hopes.

Minimizing the number of people receiving low levels of education is the most obvious policy response to Bopp and Minder's evidence. As those receiving little education usually are the more disadvantaged members of the population, the appropriate policy initiatives will enhance the educational facilities in working class and immigrant communities. Initiatives might include free nursery education, lower teacher to pupil ratios, free school meals, and wages for those who stay in school after the minimum school leaving age.

The design of further policy initiatives will depend on a more detailed understanding of the education–health relationship. At least five causal processes could contribute to the regularly observed association between education and health.[2] The material and cultural resources of the family of origin have a major influence on a child's educational attainment, so the association between education and health could be due to the long-term influence on adult health of childhood circumstances. Second, educational qualifications are a strong predictor of occupation and income during adulthood, so the association between education and health could be due to the contemporaneous influence on adult health of adult circumstances. Third, length of education may influence receptivity to health education messages, either because such messages are written in the language of the educated, or because the material and cultural resources of the educated allow them more easily to adapt their behaviour. Fourth, the association between education and health could be due to a third, background, variable which influences both the capacity to complete a prolonged period of formal education and the capacity to maintain health and cope with disease. Social psychological constructs, such as self-efficacy and time preference, have been suggested; although, presumably, affluence and enthusiasm for education in the family of origin would have a similar effect. Finally, ill health during childhood could both limit educational attainment and predispose towards adult morbidity and premature mortality. Each of these several processes is plausible biologically and socially, but each has quite different implications for health policy and the design of interventions to reduce inequalities in health. The policy and intervention hopes of Bopp and Minder, in consequence, should be shaped by attempts to unravel the causal processes which link education and health.

The most sustained investigation of these questions has been conducted by Professor Jerry Morris at the London School of Hygiene and Tropical Medicine. In an ecological study,[2] based on local education authority areas, Morris and his colleagues demonstrated a strong inverse relationship between deprivation and examination results at age 16 years. Rank correlations were found of –0.93 and –0.89 between education and, respectively, the Carstairs and Townsend index; social deprivation thus explaining statistically more than three-quarters of the variance in educational attainment. The massive impact of deprivation on education is known to government,[3] but is acknowledged rarely in policy debates. Education showed similar, if weaker, correlations with the various measures of mortality; ranging from –0.60 (infant mortality) to –0.77 (male all-cause mortality). In other words, the educational attainment of adolescents predicts the mortality rate of their parents' and grandparents' generation, as well as that of their younger siblings. In multiple regression analyses, controlling for deprivation weakened the education–mortality relationship more than controlling for education weakened the deprivation–mortality relationship; suggesting that material circumstances are more important to mortality risk than education (a conclusion supported elsewhere[4]). Because the results of the multiple regression analyses varied somewhat, depending on whether the index of Carstairs or Townsend was used, the study was repeated using the Department of the Environment's summary index of local conditions in England.[5] Once again, deprivation not education had the stronger association with all-cause mortality; although an education effect remained for coronary heart disease mortality and infant mortality.

Morris followed these ecological analyses with a study using individual-level data.[6] In these analyses, the association of self-reported health status with deprivation was stronger than with

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educational attainment. An independent effect of education remained, however, for longstanding illness among men, but not women, and for self-assessed health. In terms of the causal processes sketched above, Morris' investigations show that a considerable proportion of the relationship between education and health can be accounted for by education acting as a marker of adult socioeconomic circumstances. Education retains an independent effect, however. Which of the other causal processes account for this independent effect remains an open question, although the ecological cross-generation finding points to the possible importance of childhood circumstances. Morris planned a more direct investigation of the influence of childhood circumstances, together with the influence of age at health behaviour change, potential third factors and childhood illness, in one of the British birth cohort studies. Support for these investigations, shamefully, was refused. As a result, the baton is lying there, waiting for someone else to pick up.

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